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Determining factors in process of socio-technical adequacy of renewable energy in Andean Communities of Salta, Argentina

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ABSTRACT

The use of renewable energy presents a great potential to solve energy problems in remote communities. However, in populations of the northwestern of Argentina, there are a large number of abandoned devices. This situation motivated the research on the processes of 'technology transfer', in order to make theoretical and methodological contributions to help to improve them. The development of this work was based on the analysis of case studies in the Andean communities of Cabrería, San Juan and Las Capillas (Province of Salta, Argentina) where solar water heaters were 'transferred'. The main results presented in this paper are the identification, assessment and analysis of factors and sub-factors that conditions the analyzed processes. There were identified the following determining factors: solar technology, community participation, involvement of technicians, inter-institutional coordination, logistics and monitoring of the project, and structure of the community. The analysis of interaction showed a strong interdependence among factors, in this manner; the way in which a factor is applied directly influences the development of other factors. Finally, it should be noted that although the analyzed experiences have much in common, each situation of socio-technical adequacy is particular and therefore it requires the opening-up of researchers and technicians to adapt technologies and methodological approaches of these processes.

Contents

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1. Introduction

This paper presents the results of a research focused on the analysis of technology transfer processes for the utilization of solar energy in Andean communities [1]. Three research and extension projects (National University of Salta -UNSa-) served as support the study: Latin American Award Project to the Participatory Action Research, Mothers and Grandmothers of Plaza de Mayo (2009–2010) ''Participatory Action Research for the appropriation of technologies in use of Solar Energy for the purification and heating of water for sanitary use in isolated Andean Communities from Argentina'' [2]; University Volunteer Project 2010 ''Water heating for domestic use by Solar Energy in Community of Cabrería, Province of Salta'' [3]; and Research Project No 1900 (2010–2013) ''Tools for the improvement of Technological Appropriation processes. Interaction or Transfer?'' [4].

Renewable energies and energy efficiency measures are viewed as: resources to improve the living conditions of the population, response to environmental issues and strategy for local and regional development [5–11]. However its potential applications and benefits, not always the appropriation of these technologies is 'successful' and many difficulties associated with this 'transfer'[1] can be observed in the practice. In general, the use of renewable energies in local and regional levels is not widespread, and there are only specific facilities that in many cases do not hold up over time. In this regard, one of the major concerns in the scientific and technological field is to explain why the proposals and programs of technology transfer fail [12].

With different approaches, diverse authors have dealt in particular to explain some causes of this problem for the processes of technological transference of renewable energies:

Figueroa et al. [13] focus the analysis on the lack of insertion of renewable energy technologies, on the one side with ignorance of their potential, but also and mainly in the fact that they represent a cultural change. These authors argue that several projects addressing this issue have failed, because they have focused on the technical side and they have not considered the cultural aspect. Harnessing direct solar energy, of high intensity but variable in time, rather than concentrated on constant energy as that of a fossil fuel, requires a change of habit without which this appropriation is not feasible.

Through a diagnosis of solar energy in the province of Salta, Belmonte et al. [14] identify the following limitations and barriers for the inclusion of renewable energies: the misidentification of priorities and needs; insufficient consideration to cultural matters, organizational and social problems in local levels, previous failures in technology transfer processes; limitations on the scales of implementations of interventions and the availability of resources; lack of local training; absence of maintenance and monitoring of projects; the non-existence of a competitive market; little diffusion of renewable energy technologies and structural problems in the province.

In global scales (national, regional and international level), diverse authors identify common barriers and difficulties to the adoption of the tie RETs to tecno-economic and sociopolitical aspects. They exemplify this diversity of scales, the works of Sahir for Pakistan [15], Sudhakar for India [16], Black for countries of Europe [17] and Doner at international level [18].

From a more general perspective of the processes of technological transference (that surpasses the scope of the renewable energies), new contributions and elements to the discussion of the problematic and adoptions of technology are integrated:

Ocampo Ledesma et al. [12] refers to the process as an act of communication, where the senders are receivers and vice versa. Viewed this way, the transfer requires adaptations, special languages, trust and understanding between the parties. They are not exempt from symbolic use, local elaborations, interests and domains.

Garrido et al. [19] focus their vision on the analytical reconstruction of the processes of adequacy and socio-technical resistance, highlighting its role on the relative 'success' or 'failure' on the implementation of technologies. The socio-technical approach overcomes the deterministic limitations associated with static notions of transfer and diffusion, in which the non-adoption of a technically 'well designed' device is explained by 'social' reasons, or is considered that a device was technically 'poorly designed' if 'cultural norms' were not taken into consideration. For these authors, the socio-technical adequacy of a device is based on the stable joint of socio-technical alliances. A socio-technical alliance is a coalition that is formed as a result of a movement of alignment and coordination of heterogeneous elements such as artifacts, ideologies, regulations, knowledge, institutions, social actors, economic resources, environmental conditions and materials [20].

These concepts are integrated into the theoretical framework of the social technology by Dagnino et al. [21], who argue that ''the interest, negotiations, disputes, strategies associated with human elements, as well as aspects of others non-human elements and its corresponding relative endurance and strength, would be the starting point to understand the dynamics of a society in which both, the sociological and technical considerations are inextricably linked''.

The complexity of the problematic of the processes of technological appropriation is previously demonstrated in the presented/displayed positions. In particular several authors agree in characterizing renewable energies within a tecno-economic system, different from the conventional systems not only in terms of characteristics of the power plant and their technological aspects but also in their space density, structural and organizational elements, practical regulations and management [22]. The complexity of each interaction between multiple technical, social, economic and environmental factors associated with these systems entails necessarily to an integral analysis of the problematic [11,17,23,24].

In this context arises as a particular objective of this work, to move forward in the identification of key factors that determine the 'transfer' projects of solar technology in local areas. The development of the research is based primarily on the analysis of 'transfer' processes of solar water heaters and other renewable technologies in Andean communities of Cabrería, San Juan and Las Capillas (province of Salta, Argentina). The methodological basis is sustained in the application of participatory consultation techniques, in order to integrate the views of multiple actors involved in the processes of technological appropriation, and in a qualitative and quantitative analysis for the interpretation of obtained results (triangulations and multi-criteria evaluation).

The determining factors identified from local experiences, may potentially be considered as a starting point for analyzing other cases (geographic diversity and/or types of technologies 'transferred'). However, the scope of the research is more o riented to promote reflection on these socio-technical processes, opening the discussion and rethinking these issues, often 'taboo' in the scientific and technical traditional positivist community.

[1] Within single quotation marks are accentuated some terms commonly used to refer to this processes. The same ones aim to raise the issue from a known language and usually used, but it not implicate a conceptual adherence to its meaning. A more detailed discussion of the epistemological scope of these words is addressed in Section 2.

2. Conceptual review

2.1. From technology transfer to the socio-technical adequacy

For several years, researchers, technicians, extension workers and others involved in the 'transfer' of technologies raised the discussion of the term to refer to these processes.

Traditionally the term of *technology transfer* is understood as the movement of technologies' products and processes (or information about them) from the university and other research centers to other actors in society [25]. From this vision it can be defined as a linear process, unidirectional, of knowledge and capabilities, through which technology flows from supply to demand. Besides, this notion of transfer entail the permanent identity of a device, regardless of the socio-historical setting in which it is inserted [20].

Some authors deepened the concept of 'technology transfer' incorporating in its definition elements of participation and reciprocity among different actors involved (scientists and community). Thus, the transfer is understood as an act of communication, where senders are receivers and vice versa, resulting in a participatory, interactive and multidimensional process [12].

Other authors suggest new meanings for the naming of these processes, including: adoption, innovation and technology appropriation.

From the viewpoint of small producers, Cáceres [26] raises the concepts of innovation and technology adoption, considering that both terms are not synonymous. *Technology adoption* refers to the incorporation into the productive systems of technologies coming from outside of the production units (exo-technologies), through a process of 'transfer' where producers have no intervention over them. In contrast, raises the concept of *technological innovation* as broader and overarching. This term refers to those technologies that producers take from the context but, as a result of processes of experimentation and adaptation of technology, have been modified and/or generated by the same producers (endo-technologies). With regard to this term, Cyrulies et al. [27] define 'innovation' as "a social and interactive process that involves the productive adoption of new knowledge and its incremental advances in the context of a specific and systematic environment (…), resulting in an improving factor in the quality of life of the social relations and in production units."

Moreover, the concept of*technological appropriation*, defined from the viewpoint of the Information and Communication Technologies (ICTs), consist into making your property something that is new, foreign or strange. It should be understood in relation to particular individuals who, during their daily lives, receive mediated messages, they talk about them with the others and through a continuous process of discourse elaboration integrates them into their daily lives [28]. The concept of appropriation is similar to technology transfer but defined from the perspective of the users-beneficiaries of the technology.

The linear and unidirectional positions rose until now to the terms transfer, adoption, innovation and appropriation, do not consider that every case of implementation of a technology brings its own actions of technological development, cognitive operations and user-producer relations.

Thomas et al. [20] propose the term *socio-technical adequacy* to refer to these processes. This new meaning implies production processes and social construction of the utility and operation of technologies involving various stakeholders (users, beneficiaries, government officials, NGOs, etc.). The operation of an artifact is socially constructed assessment of a technology and not a derivation of its intrinsic properties.

2.2. Social technology

The various positions on the process of technological change also imply different conceptions about the product of this process: 'technology'.

In a first approach, *technology* is a broad concept that encompasses a set of techniques, knowledge and processes used to the design and construction of objects to satisfy human needs. This concept includes not only objects but also the social processes that originated them (forms of production and organization). It is a human creation that at the same time modifies and transforms those societies who make use of it. It is not neutral, is a response with social content to a certain problem and involves a particular way of seeing the world [29].

However, the non-adoption of technologies 'technically well designed' led to designers, technologists and scientists to rethink the issues that should be taken into account when designing and implementing a technology. This reconsideration aims to achieve a satisfactory acceptability of the technology by users and its continued use over time [20,30].

In this context there are new names: appropriate technology, social technology, technology for social inclusion.

It is generally understood by*appropriate technology*, one that has been adapted with materials, technology and local sources. It is simple and cheap enough, repeated with simplicity and almost need not later adjustments. Usually refers to technologies produced in small scale (for families or communities); mature, of low complexity, low scientific and technological knowledge, low cost per unit of output, low power consumption and labor intensive [20]. This definition does not contain the fundamental fact of profit caused by their use, focusing only on the materials and construction types. Also, does not account for widespread technological elements, essential for communities, such as cell phones and radios [30]. Generally, this definition of technology is correlated with so-called process of 'transfer' and technological 'appropriation'.

On the other hand, the term *social technology* is understood as the technology aimed at solving social and environmental problems, creating social and economic dynamics of social inclusion and sustainable development [20]. This concept comprises products, techniques and/or methodologies developed in interaction with the community, and that represent effective solutions for social change [31]. Social technologies are linked to the capabilities of solving systemic problems rather than solving specific deficits. They overcome the limitations of linear concepts in terms of transfer and diffusion through the perception of integration dynamics in socio-technical systems and processes of re-signification of technologies [20]. Another way of referring to this technology is as *technology for social inclusion* [20,32].

The development of social technology or technology for social inclusion is necessarily linked to a methodological approach of the process from the perspective of socio-technical adequacy and solidarity economy, among others aspects [33].

In this line of thought linked to socio-technical adequacy and social technology, we have positioned the development of this paper. While at first this adherence was 'intuitive' (from the idea that "a transfer is much more than a transfer"'), today already has a conceptual support much stronger and more specific terms to refer to these notions.

3. Methodological design

3.1. Qualitative and socio-critical approach

The object of studying this paper is defined as purely social, as it explicitly refers to the processes of socio-technical suitability

for the construction of social technologies, and not to the study of the technologies themselves.

In this context, the debate between the quantitative and qualitative, which has been established with different intensities throughout the history of science and especially in the last century, acquires meaning. The social, as object of study, it seems to mark one of the points of origin of the dispute with various statements and positions [34].

The main difference between the approaches of research called quantitative and qualitative lies not just in the use of numbers in the first case, and in the no use of these in the second. The differences of epistemological and technical type, which can be identified in these two ways of approaching the research, come from two basic elements: the type of intentionality and the kind of reality that both approaches seek to address research [35]. Quantitative approaches focus on the explanation and prediction of a reality considered in its most universal aspects and viewed from an external perspective (objective), while the focus on a qualitative form of research is based on understanding a reality considered from its particulars aspects as a result of a historical process of building, and viewed from the logic and feelings of their protagonists, that is from an internal perspective (subjective) [34,36].

In qualitative research inquiry is guided by what some call an emergent design, in contrast to a previous design. For Sandoval Casilimas [37], emergent design is structured from the successive findings that are made during the course of the investigation; this is, when the investigation was being held. The validation of the conclusions drawn here is through dialogue, interaction and experience which are set by consensus born of sustained exercise of the processes of observation, reflection, dialogue, construction of a collective sense and systematization. The qualitative perspective implies not only an *effort of understanding, interpretation and dialogue*, understood as the acquisition of a sense of what the other or others mean by their words, their silences, their actions and their immobility. This approach also implies the possibility of creating generalizations, which allow to understand the common aspects to many people and groups in the process of production and appropriation of the social and cultural reality in which they are developing their existence.

There is a third paradigm of research: 'socio-critical'. The researcher's task is moved from the analysis of social transformations to the involvement of researchers in solving problems from the self-reflection. This involves a constant interplay between action and research. It aims at the use of knowledge, the action is a source of knowledge and the research is in itself a transformative action [38]. In this approach the methodologies of Participatory Action Research are registered.

This research adopts qualitative and socio-critical methodological approaches, in order to analyze the processes of socio-technical adequacy from the perceptions of those who were involved, as well as to build conceptual contributions and methodological proposals to address them and improve their practice.

Several works related to the analysis of barriers, diffusion and appropriation of the RETs, in different contexts and countries, have adopted a methodological approach in the same line of this work. The consultation to social actors is valued like a substantial strategy [24], standing out as a participating tool to the use of surveys, interviews and factories [7,16]. Also the frequent use of case studies like methodological strategies to analyze the processes of adoption of RETs (Examples, Maharashtra, India [16]; Pangan-an Island, Philipines [39]; Rural areas of Scottish [40]; mountain communities of the Hindu Kush of the Himalayas (China, India, Nepal and Pakistan) [11]. In many cases the perceptions of the social actors and the analysis of the case studies are systematized group problematic and factors in classifications and thematic categorizations that allow visualizing integrally results [9,16], in agreement to which in this work it is defined as triangulation. The multi criteria evaluation of the analysis is especially considered for the evaluation of the RETs, the multifacetic nature and the diversity of components and involved interests. Between the most frequent applications of EMC, tie to renewable energies, stands out: the detection of priorities, analysis of alternatives and comparison of factor critics, generally, focused on decision makers [24,39,41,42].

In the following used methodological aspects, particularly in this work, are deepened.

3.2. Selection of case studies

The universe of study, or 'area of analytical interest' [43], defined for this research is confined to the Andean communities of Salta. These communities present as a distinctive feature, a large potential for harnessing solar energy, in function of: a high solar resource availability in quantity and quality throughout the year, difficulty in accessing traditional fuels due to geographic isolation and shortages of firewood by the arid conditions of the region.

Within the area of interest two case studies (projects) have been selected for analysis, involving three experiences of technology transfer of solar use. One of both projects was developed in the community of Cabrería (Calchaqui Valley Region) and the other communities Las Capillas and San Juan (Eastern Valleys Region of Height). The strategy of sample selection (case studies) corresponds to an intentional non-probabilistic sampling (intentional) [44]. The criteria for selection of cases were based on the similarity between them, regarding the environment and socio-economic characteristics of communities, the methodology used in technology transfer (Participatory Action Research) and transferred technologies (solar water heaters and other solar thermal technologies). In addition to the selection of cases, the possibility of financial support for field work, travel and access led to communities, other research and extension related projects [2–4].

The main difference between the study held in Cabrería and the analysis of the other two communities lies in the timing and monitoring of the project. For Cabrería, it was possible an accompaniment of the process (2009–2011), with direct participation in the activities and closer connections with the set of actors [2,3]). For Chapels and San Juan, we performed a later analysis of the project completed in 2006 [45].

In this work 'case studies' are adopted as a strategy of analysis and observation of specific situations in-depth. What defines the inclusion of cases are the question and the purpose of the research [44], in this study: What are the main factors or elements that influence the processes of socio-technical adequacy of solar energy in Andean communities Salta?

3.3. Tools for data collection and analysis

Various techniques were used for data collection and analysis of case studies. Although, the data collection tools were preselected at the start of the work, the way they were implemented has had to adapt during the development of the process, consistently with the idea of a dynamic and emerging qualitative design [37]. Thus, the content and number of interviews, field trips and participatory workshops, among other things, were adjusting throughout the development of the work. Similarly, in order to define "indicators for the evaluation of the processes of

Table 1
Methodological tools for data collection.

Methodological tools	Objectives	Features and applications
Documental analysis	Get to Know and contextualize the projects and communities selected as case studies	It included secondary information, environmental places and socio-economic characteristics, precedents of research and extension. [2–4,13,45,47–51]
Participant observation	Experiencing 'from within' [52] the development of the project and establish direct contact with the various actors involved	It was only applied in the case of Cabrería. Based on the direct participation of one of the researchers in the various activities of the process of 'transfer' from its formulation and implementation (community workshops, technical meetings and travel). The researcher, who joined the coordination group of the project, had a decisive role in the motivation, planning and organizing of its different stages [53]
Workshops/Participatory assemblies[a]	Obtain the collective perceptions. Analyze the role of each of the social actors and the interactions between them	Was only applied in the case of Cabrería. It included the execution of five meetings with the community; in which were covered various topics of technology and the methodology of 'transfer', and they make decisions jointly [53,54]
Interviews	Investigating perceptions and individual assessments of different actors involved – technicians and community – about the process of transfer and the technology itself.	It focused on the performance of semi-structured interviews to community members and technicians who participated in the processes [54]. Total interviews: Cabrería – 24, San Juan and Las Capillas – 12

[a] The 'workshop' is a tool for socialization; in which we shall learn to think and act as a team, is an educational process in which the participants assume specific problems and issues through an integrated approach, where it rules the reflection and articulation of the theory and practice as a driving force of the process; and they are oriented towards a constant communication with the personal and social realities. Is also a mean of collecting information, of a collective nature, in contrast with the personal uniqueness of the interview [37]. 'Assemblies' on the other hand, are meetings where members of an organization or everyone affected by a particular matter, can give their opinion or decide on a topic directly and without representatives.

Table 2
Methodological tools for data analysis.

Methodological tools		Objectives	Features and applications
Triangulations [55]	Methodological triangulation	Characterize the communities and projects. Systematize the perceptions of the different stakeholder groups.	Included the systematization and integration of the information collected for each project (case study), based on the several collection methods used: interviews, workshops, document analysis and in-situ observations. (Fig. 1)
	Data triangulation	Identify determining factors and sub-factors for the processes of socio-technical adequacy.	Included on one side the triangulation of perceptions of different actors (Fig. 2) and second, the comparison and integration of the experiences analyzed (Fig. 3) for the definition of the determining factors common to both processes
Evaluation of determining factors	EMC technique: pairs comparison	Identify critical sub-factors relating to each factor.	To obtain the critical sub-factors, was used the methodology proposed by Saaty in 1980 [56–58], which allows the comparison of criteria according to their relative importance between pairs of elements in a matrix of preference. We used the scale of values given by the same author [57] and the geometric measurement as the procedure of mathematical calculation. This matrix has reciprocal properties
	Dynamics of interaction among factors	Examine the interaction among the determining factors and their degree of influence in the processes of socio-technical adequacy	It consisted of an adaptation of the technique of social analysis 'Dynamics of skills' [34,59]. We worked with a matrix of double entry considering the interrelationship of all factors. For the evaluation we used a scale from 1 to 5, where 1 implies little or no contribution and 5 a total contribution of the factor of the row in the column factor. In this case the matrix is not reciprocal

technology 'transfer'" in this first approach the "identification of factors[2] that critically affect the sustainability of 'technology transfer' projects" was conducted. This led to restructuring the way of analyzing the case studies, defining new tools of analysis for factors, such as EMC techniques.

In Table 1, are presented and briefly described the data collection techniques; and in Table 2, the interpretation and analysis tools used.

[2] A factor is an element or circumstance which contributes, among other things, to produce a result [46]. Generally is defined as "something that should happen or should not occur to achieve a goal". In this work, are called 'determinant factors' all the elements, that according to its application, may favor or disfavor the technology transfer processes. At the same time they are subordinated by a set of sub-factors that characterize them.

4. Case studies

4.1. Characteristics of communities

Andean communities have particular geographic characteristics. Although located in different sectors of the province of Salta, the communities analyzed present common features as for its topography, climate, vegetation and even socio-economic conditions.

The topography of the Andean region is rugged, consisting of mountain ranges, intermountain valleys (Cordillera Oriental range), plateaus (Puna) and more extensive high valleys (Valles Calchaquíes) [60].

Cabrería is located in the Valley of Luracatao, belonging to the Municipality of Seclantás, Department of Molinos. This department is situated in the center of the Valles Calchaquíes, being

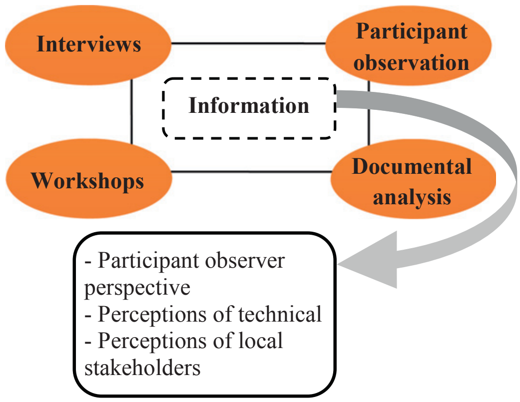


Fig. 1. Methodological triangulation scheme to obtain perceptions.

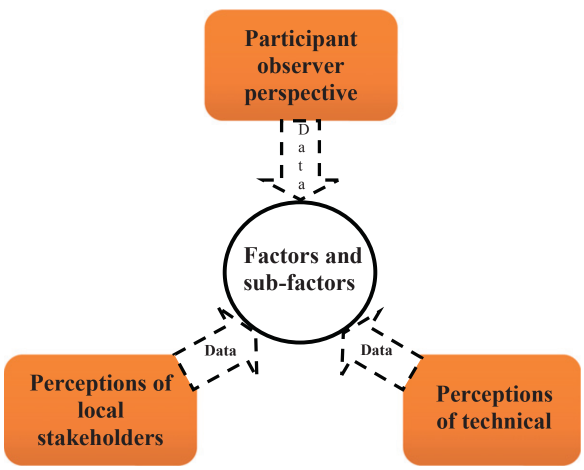


Fig. 2. Data triangulation scheme to obtain the determining factors in each case study.

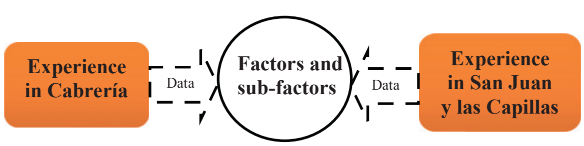


Fig. 3. Triangulation scheme among the experiences analyzed.

extremely mountainous, with altitudes that fall from west to east from the 5000 m to 2000 m. Luracatao area corresponds to Semi-arid Valleys of Height; their average height is 3000 m to 3200 m.

The communities of San Juan and Las Capillas are located in the intermountain valleys of the Cordillera Oriental range. They are located within Finca El Potrero, near the community of San Isidro, Chillalloc and the places named El Chañar and Tacopampa. Within this territorial unit it is also located the town of Iruya, capital municipality of the homonymous department. They are located on the eastern slopes of the Sierra de Santa Victoria, the boundary between the provinces of Salta and Jujuy, with an average altitude of 4600 m.

In Fig. 4 it can be observed the location of community case studies and some images of their landscape. From this figure we can appreciate the distance and difficulty of access to these villages with regard to the Capital city of the province of Salta and the main characteristics of socio-environmental surroundings.

The prevailing climate in the area is semi-arid high mountains. Rainfall is concentrated between November and March and does not exceed 300 mm/yr. The climatic conditions of aridity, is due to the presence of mountain ranges that prevents the passage of moist winds from the east, impacting significantly on rainfall [61]. Heavy rainfalls are usually the torrential rain type, causing river floods and erosion processes. The average minimum temperatures are between 8 °C and 15 °C and recorded significant daily thermal amplitudes up to 20 °C. The heliophany is important. Total radiation measures were recorded on horizontal surface near the 1000 W/m^2 in the colder months [47].

In general soils are young and poorly developed with abundant coarse material, low moisture retention, and poor in organic matter, nitrogen and phosphorus [60].

The area of Cabrería has a vegetation of Prepuna and Monte [60], with presence mainly of algarrobos (*Prosopis* sp.), tala (*Celtis* sp.), brea (*Cercidiium* sp.), chañar (*Geoffroea* sp.), Jarrilla (*Larrea* sp.) and different species of cacti. In the intermountain valleys where are located San Juan and Las Capillas, the vegetation is high Andean highlands and highland pastures of the Yungas, as we descend in altitude [60]. The steppe is poorer, leaving large areas of bare soil and allowing only the development of cacti, xeric and coarse grasses [47].

These physical and natural aspects directly influence the socioeconomic characteristics of the communities. They are usually small towns limited by the availability of resources. In the case of Cabrería is constituted by 35 families, San Juan 22 and Las Capillas 6. The population has a high percentage of UBN (Unsatisfied Basic Needs) that exceeds 65% [47,51]. Most of these communities have a lack of electricity, gas and water network. The household economy is based on agricultural and livestock production, primarily intended for auto- consumption, and the elaboration of different artisanal products that together with the surplus of agricultural production goes to the local market [45,47,48,51].

Regarding to the energy issue, they use large amounts of fuel to generate heat to carry out subsistence activities. These are purchased at high costs because of the geographic isolation found in most communities, or they can use wood from the location, obtained with effort because of the aridity of the area [13].

4.2. Overview of projects

The following criteria have been taken into account for the selection of case studies: community characteristics, type of technology and methodology used in the process of 'transfer'. The project characteristics are given by the last two criteria.

In general, the methodology of 'transfer' used was the Participatory Action Research and the common technologies were solar water heaters. However, there were significant differences between the projects, which are detailed below:

4.2.1. Cabrería

Transfer activities of solar water heaters in the community of Cabrería was conducted initially with funding from two projects: Latin American Project Award to the Participatory Action Research, Mothers and Grandmothers of Plaza de Mayo 2009, "Participatory Action Research for the appropriation of technologies in use of Solar Energy for the purification and water heating for sanitary use in isolated Andean Communities from Argentina" [2], Ministry of Social Development of the Nation and the University Volunteer Project 2010 "Water heating for domestic use, by solar energy in Community of Cabrería, Province of Salta", Ministry of Education of the Nation [3].

The demand for water heaters was a request originated from the community. Through a previous project we had obtained the funding for the building and improvement of bathrooms. After the

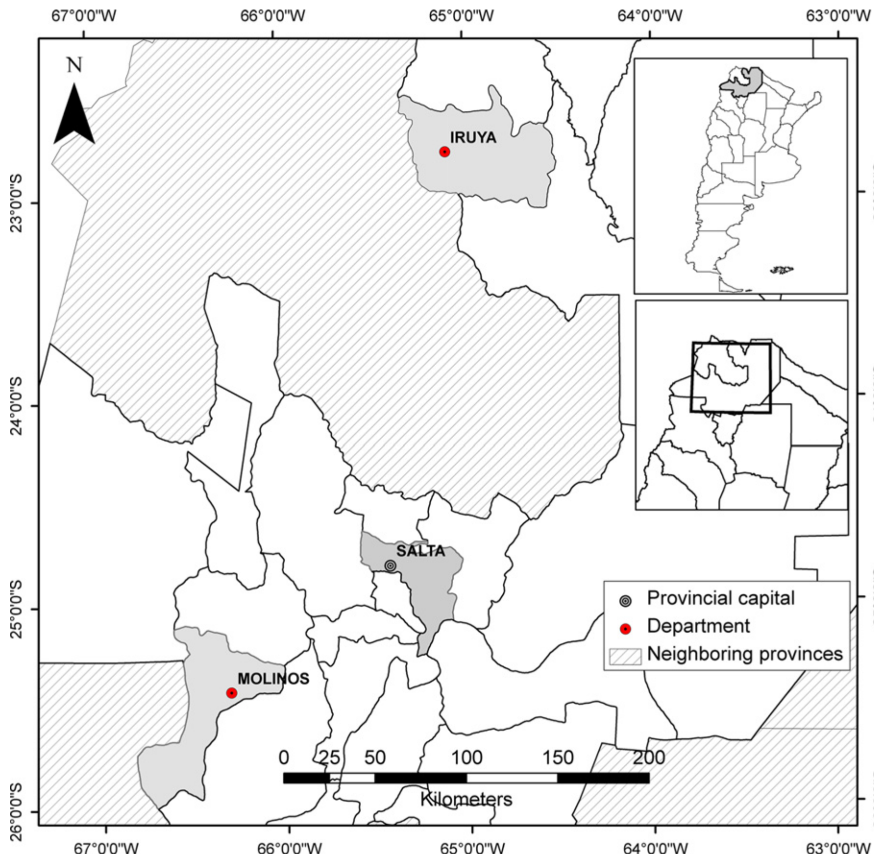


Fig. 4. Location map Cabrería, Las Capillas y San Juan community, in the province of Salta.

realization of it emerged the need of having hot water to the shower [53].

The solar water heaters emerged as a viable option, to meet the need of having hot water in the community, for two reasons: the availability of solar resources in the place and the lack of other energy sources (natural gas, electricity and firewood shortages).

The project was planned with the participation of the three institutions involved. Emerged as a proposal from the INENCO (Research Institute of Non-Conventional Energy), to the IPAF NOA (Research Institute for Small Family Farming, Argentinean Northwest head office), who proposes to work with AERs (Rural Extension Agencies of Seclantás and San Antonio de los Cobres) [53]. The latter two organizations are dependent on the National Institute of Agricultural Technology (INTA).

The theme was established by the Ministry of Social Development of the Nation who funded this first edition of the Latin American Award for Participatory Action Research—Mothers and Grandmothers of Plaza of Mayo. Researchers invited to participate in different lines of action research including the Alternative Energies [54].

Transfer activities were motivated from the AER of Seclantás, inviting the 35 families that constitute the community to participate, of which 24 chose to participate initially in the water heaters' project. After beginning the process, four more families joined [53,54].

Project development can be summarized in the following times and activities:

1. *Diagnosis and precedents*: Since 2001, the Rural Extension Agency of Seclantás (AER), enter the Valley Luracatao to begin a series of Participatory Rural Appraisals. At this time there were no precedents of community actions to promote rural development in the area. From there, the first community projects were related to health-care aid kits to animal improvement, and then with the access to drinking water, as a priority need identified in the community. More recently the revolving fund of veterinary products, the construction of wood saving stoves-oven, and the construction and improvement project of bathrooms came up. The community played an important role in the development of these projects, from their planning to their execution. It is throughout the bathrooms project that the community starts to think about the possibility of having hot water for bathing. The project of solar water heaters emerged as an alternative to meet this demand and at the same time as a help to solve, at least in part, the shortage of firewood.
2. *Inter-institutional coordination and organization:* Seeking to focus the analysis from a comprehensive, multidisciplinary view, a team was formed with technicians from the participating institutions. Also, a hand of engineering students in Natural Resources and Environment, from the National University of Salta joined the team. Throughout the project, meetings of articulation, debate and general coordination of institutional actors were held. There were instances of training on the IAP approach, of theoretical content discussion, of defining the role of each institution in the process and steps for joint action. The definition of a coordinating Group 'Device' with the task of motivating, designing and evaluating field activities was formed too. At this point, the role of the Rural Extension Agency was emphasized, which conducted the field support activities and provides the link between communities and other actors.
3. *Presentation, testing and selection of technology:* In order to get the community to learn and get involved with technology, the following activities were conducted: audio-visual workshops,

instances of direct observation and testing of three types of solar water heaters, in some families. For the selection of technology the residents valued, after the test, the following characteristics of the water heaters: water storage capacity, duration of hot water, durability over time (robust, longer life), price (economic), capable of mobility from one place to another, capable of being repaired within the community, ease of installation, speed of heating the water, affordable and accessible parts, it can be placed on the roof, it is likable (aesthetics), for daily use, the water can be used for many things (kitchen, shower, etc.).

4. *Modification of technology:* Right from the first installation of water heaters and the experience of their use by the community, it was necessary to make some modifications, allowing the improvement of their benefits. The adjustments that have been made are the followings:—enlargement on the solar collector area, changes in the float and the addition of an individual output for hot water.
5. *Training:* During the participatory workshops, the community appointed a group of young people with technical skills in plumbing (who had already participated in the construction of toilets) for their installations and to be trained in the use of solar water heaters. Training was provided at various locations and moments: in the field, during the installation of water heaters, and in workshop facilities of INENCO at the National University of Salta.
6. *Installation of water heaters*: The installation of water heaters went underway in several instances (2010–2011). The equipment was installed in small groups according to the dynamics of exchange with the community and the potential relocation and logistics. Initially the installations were conducted with technical support from INENCO, but then were continued by the trained young people in the community, local group of installers.
7. *Monitoring of the transfer:* Currently the project is still at the stage of monitoring and diffusion. At the time of the last field survey (August 2011), the totality of water heaters were not installed. With respect to those that were installed by the technicians and the community itself, most are working properly. Also the users' guides of water heaters that should be delivered to users, are in process of production.

4.2.2. San Juan and Las Capillas

The project, in which was framed the transfer of solar equipment for the communities of San Juan and Las Capillas, was called "Participatory Action Research and exchange of knowledge regarding the utilization of alternative energy in the community of Farm El Potrero, department of Iruya, Salta", and was funded by the University Volunteer Program 2006 Department of Education, Science and Technology of Argentina [45,48], through the National University of Salta.

The project exposed as an aim the improvement of the living conditions of the mentioned communities, meeting the identified demands by the farmers themselves. Diagnoses have been made in the context of a project of Development of Indigenous Communities [47]. We applied a participatory methodology for the transfer in the identification of problems as in the development of the appropriate technology and equipment installation [13].

The need addressed in the communities of San Juan and Las Capillas was referred to the hot water for domestic use, through the installation of family solar water heaters and a communal laundry room, respectively.

The proposal analyzed here was a result of the joint work developed by the communities of Finca El Potrero, the Directive Commission of the Community Center that gathers, field technicians of the Height Valley Network (NGOs), the Agricultural Social Program of Salta (PSA), the Project of Indigenous Communities Development (National Institute for Indigenous Affairs), teachers and students of National University of Salta and the Institute of Non-Conventional Energy Research (INENCO) [45].

In San Juan a total of 12 families as well as a school, that decided to participate in the project, were benefited. For Las Capillas, the main beneficiaries were the school children and women of the community who are responsible for washing clothes.

This project also involved two more communities of Finca El Potrero: Chillayoc and San Isidro, but were not included in this paper. They transferred different solar energy technologies (solar panels and water heaters), according to the needs and characteristics of each community.

The most relevant stages of the project were:

1. *Diagnosis:* From participatory rural appraisals carried out by INAI technicians and students, different problems were detected in these communities, such as: fuel shortages and lack of time to search, physical discomforts as a result of carrying by women and children; lack of hot water for washing and personal cleanliness as the high cost of bottled gas. In the community of Las Capillas emerge the concrete demand by women for hot water, to wash clothes and clean the children, due to low temperatures especially in winter. Women expressed the need for the creation of a communal laundry that allows retaking the tradition of washing clothes in a group. This activity used to take place in the river and was a social meeting place but this practice was cut due to "volcanoes" (lava flows of mud or casting clay) that chocked stretches of the river. For the community of San Juan, PSA technicians received the proposal to join the Volunteering Project to replicate the experience of the communal water heater in the community of Las Capillas, either to laundry or showers. The project of solar water heaters was raised from firewood savings which would take place from the utilization of the solar technology. In participative workshops was finally decided to install family and no communal equipments in San Juan, in response to the scattered location of the population and organizational problems of the community.
2. *Inter-institutional coordination*: institutions that participated in the project (Height Valley Network, Agricultural Social Program and Institute of Indigenous Affairs) had a history of work in the area, in research and development projects linked to the productive and organizational problems. In the instance of diagnosis, when arise the demand for hot water, field technicians are brought into contact with the teachers of UNSa and technicians of INENCO. Finally, in the formulation and development of the project, the technical group was formed by all these institutions.
3. *Presentation, selection, testing and adequacy of technology:* To select the right kind of solar collectors that has to be build for housing of San Juan and the communal laundry in Las Capillas, the following conditions were taken into account: low cost, light equipment (which could be transported by foot or by mule on difficult trails), construction and simple repair, constructed with materials resistant to wind and solar radiation. On the other hand, the idea was to focus on design, development, review and evaluation of the technology with the communities themselves. In this aspect, different prototypes were scaled, tested and adapted to define the model of the equipment that would be installed.
4. *Installation:* The collectors (16 equipments) were transported unarmed and packed through mountain path up to the

community of San Juan. The transportation was conducted on foot and with mules for university students and community members. Installation was simple and the neighbors were trained to assemble the equipment. Each family prepared a flat horizontal surface prior to placement of the solar collectors. During the construction and installation of water heaters, the functioning and maintenance needed to keep the equipment in working order was explained to take advantage the equipments of the best way [13]. In the case of Las Capillas, the location for the communal laundry was selected according to the technical conditions (solar radiation, slope, water availability, location for installation of sinks and drains) and social (avoid conflicts in the community). The solar collector, which had previously been assembled and tested in the experimental field of INENCO, was installed in Las Capillas by the team of volunteers, technicians and members of the community.

5. *Monitoring:* After the installation of water heaters in Las Capillas, technicians had no resources to return to the area. In San Juan the second batch of water heaters were installed by the inhabitants themselves and a visit to verify the installation and operation of equipments, in the first few months, could not take place either [54]. From a recent survey conducted in the framework of this research, we found that from the year of installation and until now, the water heater of Las Capillas is not in operation [1]. In San Juan we conducted a survey in 2007, by one of the technicians who participated in the original project [49] and another in 2010 as part of this research. In the surveys there was found that from the total of installed water heaters, only four were kept in perfect condition and seen as fully operational. The school's equipment was also in good condition but it was not in use. The rest of the equipments were broken, and therefore the families were not making use of water heaters [1].

5. Determining factors in processes of socio-technical adequacy

5.1. Identification of factors and sub-factors

From the methodological and data triangulation of the experiences analyzed (case studies in Andean communities), we identified six determining factors of these processes: (1)—solar Technology,[3] (2)—participation of the community, (3)—participation of technicians, (4)—inter-institutional coordination, (5)—logistics and project monitoring, and (6)—structure of the community. For each factor are also defined, a set of sub-factors that are explained and described in the following paragraphs. They are expressed in a positive way, that is, as determining elements that *favor* the processes of socio-technical adequacy. In some cases they reflect positive conditions directly observed in the analyzed processes, and in others, refer to lessons learned from the practice and reflection on these experiences.

Determining factor 1: *Solar technology*

- *Satisfaction of needs:* Solves the problem of hot water and the users requirements in terms of temperature and amount obtained.
- *Easy use and maintenance:* The water heater is simple and practical, does not require much care and can be used by all the family members.
- *Adaption to environmental conditions:* The water heater can withstand the radiation and temperature changes without major structural damage. Also if properly fastened, it withstands high winds.
- *Good performance:* The technology heats the water to a suitable temperature and the same is available for bathing, laundry and service.
- *Adequate information:* The users have the necessary knowledge about the use, care, maintenance and operation of technology.
- *Useful life of solar water heater:* The characteristics of strength and durability of materials combined with a proper care and maintenance of technology that ensures a lifetime of at least 5 years.
- *Replicability:* Refers to the interest generated by the technology in other people and the possibility to access it.

Determining factor 2: *Participation of community*

- *Identification of actual demand:* Raising the specific needs throughout the 'beneficiaries' themselves.
- *Technology selection:* Possibility to choice and try different technological alternatives available that best meet the demands of the community and conditions of the area.
- *Socio-cultural adaptation:* Adjusting the technology to local needs and conditions, particularly considering the culture and customs of the community.
- *Training of local technicians:* Training of local technicians for installation and repair of solar water heaters.

Determining factor 3: *Participation of technicians*

- *Accompanying the process:* Active participation in the various stages of the process and interest in its different aspects, beyond of their specific work.
- *Fulfill the commitment*: Refers to the responsibility gained through the interaction with the community and the personal and professional effort put into the activities.
- *Opening-up:* Attitude of dialogue, respect for others, recognition of local knowledge and mutual learning in the interaction with the community.
- *The language of reaching:* Ability to communicate and integrate with the community in the different instances of the project (workshops, technical development, monitoring, etc.).

Determining factor 4: *Inter-institutional coordination*

- *Socio-technical association:* Relates to the effective integration of the different stakeholders involved in a project to work as a complement and enhance individual and institutional capacities.
- *Defined roles:* Clarity in the definition of functions and duties of all the stakeholders of the project.
- *Good communication:* This relates to a continuous and dynamic flow of information within and among the actors.
- *Previous contact:* Links of greater trust and credibility generated by previous work experiences of field technicians that act as reference and liaison with the community.
- *Leadership:* This refers to the existence of a leader (or group leader) that motivates, convenes and mobilizes the process activities, within each institution and in the joint.
- *Creative responsiveness:* The ability of institutions to react to unforeseen events, and to readjust the planned to the circumstances arising from the process.

[3] It is pertinent to clarify that the analysis focuses on the 'solar water heaters' as technology object to the socio-technical adequacy. The description of the sub-factors therefore focuses on the characteristics of these devices. However, it is possible to generalize with this first factor identified, the technical aspects of construction, operation and use of any technology.

Determining factor 5: *Logistics and project monitoring*

- *Flexible planning:* This refers to the intrinsic capacity of the project to modify the times and redistribute the planned resources to the requirements of the process dynamics and contingencies that may arise.
- *Respect for the dynamics of social processes:* Consider the existence of prior and simultaneous processes to the one of 'transfer' (uptime, forms of organization, other projects, festivals, etc.) that could influence the process.
- *Continuous technical advising:* Refers to the technical and solving of technological problems arising during the process.
- *Post-installation monitoring:* observation and evaluation after the installation of technology to verify its proper operation.
- *Local technical autonomy:* It is linked to the process in which the community achieves independence from the external technicians in the sustainability of the technology.
- *Evaluation of the process and results:* Analysis, reflection and continuous learning from experience, in order to improve the appropriation and contribute with other processes of local and socio-technical adaptation.

Determining factor 6**:** *Community structure*

- *Good organization:* This refers to the organizational capabilities already installed in the community, including: the existence of efficient communication flows, leaders identified, defined roles, communal areas to decision-making, exercise in conflict resolution, communal practices and actions.
- *Positive experience of previous projects:* The 'success' in the implementation of previous projects builds confidence in the community to undertake new proposals.
- *Local empowerment:* Enhancing the local capacity and the power of decision of the community from the access and generation of knowledge and resources.
- *Community values:* Features that strengthen the community as such: Sense of belonging, unity, solidarity, concern and respect for others, an attitude of cooperation, concern for the common good, etc.

5.2. Prioritization of sub-factors

In principle it is assumed a complementarity among the various identified factors and at the same time a strong contribution of the sub-factors in the characterization of each of them. However, the effort of analysis towards the prioritization of these elements is focused on the possibility of defining some key points that should be considered in the process of socio-technical adaptation, particularly of solar technology and other technologies in general. Also, the detection of critical sub-factors, the most important or the ones with more comparative weight, allows guiding the analysis of interactions among factors, focusing on their key characteristic features.

By matrices of pairs comparison, there were detected the critical sub-factors within each factor. The values assigned to each crossing corresponded to the question: How much more important (or least) is the sub-factor of the row about the sub-factor of the column in relation to the factor analyzed? For example, how much more important (or least) is the influence of sub-factor 1.1.—*A Technology meeting the needs,* in relation to the sub-factor 1.2.—*That is easy to use and maintain*, to achieve good solar technology? Or another: how much more important (or least) is the influence of sub-factor 4.4.—*Existence of a pre-contact* -with respect to the sub-factor 4.5.—*Leadership, to achieve an effective inter-institutional coordination*?[4]

This analysis revealed the following as critical sub-factors:

- *Solar technology:* It meets the need and the good performance;
- *Participation of the community:* Identification of the actual demand and socio-cultural adaptation;
- *Participation of the technicians:* Comply with the commitment assumed and opening-up;
- *Inter-institutional coordination:* Socio-technical association and leadership;
- *Logistics and project monitoring:* Compliance with the social dynamic, flexible planning, and local technical autonomy.
- *Structure of the community:* Community values and good organization.

In Table 3, shows as an example the analysis of the factor: 'Participation of the community'. The critical sub-factors were determined according to the value of the obtained weight (*W*). Those with a weight exceeding 15% are considered critical. Should be clarified, this analysis allowed to identify the critical sub-factors based on an internal comparison among them, but does not imply that the rest of sub-factors are no longer constraints to the process of socio-technical adequacy in general.

5.3. Interactions among factors

Through an adaptation of the qualitative technique Social Analysis 'dynamic skills' [22,42], we assessed the contribution and total dependence of each factor with respect to other factors and the process of socio-technical adequacy in general.

To assign values in the matrix of interaction among the factors the following questions were answered: To what degree the optimum implementation of the row factor contributes to or influences the optimal application of the factor of the column? Or how important is a better implementation of the row factor for a better application of the factor of the column?

The analysis leads to three possible results: integration, fragmentation or hierarchy, depending on the total value obtained in the matrix and the location of the diverse interactions among factors in a Cartesian graph.

Fig. 5 summarizes the results of this analysis. In the diagram, the *Y* axis represents the total contribution and the *X* axis the total dependence among factors. The interaction analysis showed a highly integrated relationship among the factors, with a high rate of interaction (above 60%) and distribution in the diagram in the upper right quadrant (Fig. 5). This indicates that there is a strong interdependence, i.e., the way in which a factor is applied directly

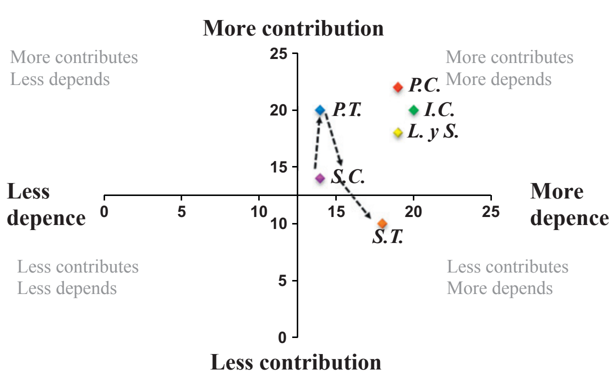


Fig. 5. Diagram of interaction among determining factors.

[4] Note the adjectives 'good', 'effective', etc. to emphasize the positive connotation of the fact.

Table 3
Comparison among sub-factors to Participation of the community.

Sub-factors	Identification of actual demand	Technology selection	Socio-cultural adaptation	Training of local technicians	W[a]	Percentage (%)
Identification of actual demand	1	7	1	5	**2.4323**	41.76
Technology selection	1/7	1	1/7	1/7	**0.2324**	3.98
Socio-cultural adaptation	1	7	1	5	**2.4323**	41.76
Training of local technicians	1/5	7	1/5	1	**0.7274**	12.48

[a] *W*: Weight of sub-factors. The calculation of the weight's vector can be addressed using different mathematical procedures. One of the simplest, used in this work consists in calculating the geometric average of the elements of each row of the matrix [57].

influences the development of other factors. Thus, the optimization of each factor will exert a positive influence on the process of socio-technical adequacy of the technology. Conversely, the lack of applying one of the factors exerts a negative influence conditioning the process.

References' factors: S.T., solar technology; S.C., structure of the community; P.C., participation of the community; P.T., participation of the technicians; I.C., inter-institutional coordination; L. y S., logistics and project monitoring.

Among the most influential factors, the participation of the community represents the largest contributor to others. This means that the optimal community participation favors the processes of socio-technical adaptation, but their absence or improper implementation can become a bottleneck. At the same time this factor has a high dependence on other factors such as inter-institutional coordination, Logistics and monitoring of the project, implying that these factors are interdependent, as well as the participation of technicians and the structure of the community.

In other words, an adequate community involvement will allow a better inter-institutional coordination, will ensure a good logistics and monitoring of the project; will encourage the participation of technicians, will favor a better socio-cultural adaptation of technology and strengthen the community structure. Moreover, to achieve an effective community participation will be required to observe the other factors, i.e., there must be coordination, monitoring, an appropriate technology, etc.

The coordination, participation of technicians and logistics also has a strong influence (contribution) among them and the development of other factors; they contribute to the adaptation of technology, participation and community structure, etc. Also the coordination and logistics require the existence of other factors to optimize its implementation (high value of dependency). Without participation of technicians and the community, without a strong local organization, without an efficient technology, it is not possible a good coordination, logistics and monitoring of the project.

Solar technology factor is the factor that contributes least to the other factors, however has a high dependency. This means that the factor has an impact not so relevant in the application of others, but for good solar technology will be essential to have a good participation of stakeholders in the identification of the demand and socio-cultural adaptation and a good coordination among the institutions.

The diagram uses arrows to indicate relationships that contradict the main tendencies of the interaction. While these contradictions are not pronounced, i.e., the integration prevails among the factors; we can observe that the elements associated with these relationships are the ones with the least contribution and/or total dependence. For example, in the case of the participation of technicians, it indicates that the effective application of this factor has little benefit to the community structure. This relationship is reciprocal. At the same time a well-built community structure does not exert a significant impact in respect to the solar technology factor. This relation in reverse is even less dependent.

In this regard, it is important to mention that from the six factors identified, the first five can somehow be guided from the planning and development of the same processes of socio-technical adequacy: the technological object/knowledge, community and technical involvement, coordination, inherent logistic in the project. But the 'community structure' is an independent factor in relation to the possible intervention of a project, as it relates to intrinsic characteristics of the community and represents a precondition that could positively or not influence in its development. However, two observations can be made in this regard. On the one hand, it is feasible (and desirable) that from the projects will be generated specific actions aimed at strengthening the community and its local development. Moreover, a process of socio-technical adequacy itself can be viewed as a concrete experience to strengthen the local community, becoming in this case, in an opportunity to improve their organization and to root its identity values, among others aspects.

6. Discussion and conclusions

In the article we have reviewed and discussed the main developments and conceptual changes associated with the term 'technology' and the process of 'transfer'. However, it is necessary to emphasize that currently these concepts and views continue to coexist in the practice of the projects and actions related to renewable energy. It would be inappropriate to issue a judgment on the common and widespread use of the word 'transfer', 'appropriation' or 'innovation'. Its meaning is varied and depends on the specific context in which its definition is used, interpreted and applied. As a result of the investigation itself, the team adheres to refer to these processes as ''socio-technical adaptation'', after going through reflections of 'transfer', 'appropriation', 'interaction',..., but not necessarily arise as the only or permanently nomination. The construction and internalization of these new concepts is an inherent condition in research in this area, where the object of study refers to purely social and dynamic matters as are the processes themselves.

In relation to the methodological issues of research, this work was approached from a qualitative and socio-critical perspective, because of the benefits that offers in the study of social processes. This approach allowed the study of the process of socio-technical adequacy in a real context and the understanding of the views of social actors through their own words, actions, interactions, etc. In general, the application of participatory techniques for data collection and triangulation-EMC for analysis, made possible to

meet the project objectives and it happened to be appropriate and satisfying for the study. Also the selection and analysis of case studies about the issue helped deepen the processes of socio-technical adequacy and consequently support the identification of its determinant factors.

During the determination of these factors and sub-factors some aspects related with the technology itself (in this case for solar energy applications) were highlighted, participation of stakeholders (community, technicians, institutional coordination), project development (planning, implementation and monitoring) and specific structure of the community (organization, values, etc.). These factors are defined as "conditionals" of the process and not as "determinants" for their existence in themselves, highlighting in the analysis the strong relationship of integration and complementarily between them.

Many of the elements identified as keys to the processes of socio-technical adequacy in this study show similarities to the contributions made in other areas in relation to renewable energy (from local to global: Valle de Lerma, Province of Salta, Argentina and other countries). As the 'more' sustainable actions strategies for the energy policy guidance in the local-regional level of Lerma Valley, Salta: the promotion of actions of coordination and inter-institutional linking, a participatory approach to planning and management, the need of technological adaptability to actual demands, the improvement in the chain of transfer and social appropriation, the inclusion of socio-environmental externalities in the energy evaluation, are proposed among other points [5,62]. In the case of the Province of Salta, stand out as favorable conditions for the promotion of renewable energy: advances in research and technological development, the availability of solar resources in the region, the possibility of a concrete response to social and productive demands from solar energy, interest in these technologies from some groups of actors, the possibility of involvement and support of various organizations and opportunities for local production and easy maintenance and low cost technologies [14]. On a more limited level to the technological process and referenced in other provinces of Argentina, Thomas and others [19,20] focus the discussion in forming socio-technical alliances, a concept that includes both conditionings, the technological and the participation ones, coordination and ideology involved in these processes. Other specific experiences developed in the country also coincide in identifying as favorable conditionings for these processes, the multidimensional diagnostic studies and the work on more comprehensive solutions, which implies the formation of a support structure with local stakeholders and exceed the view of development of a device (technology) to go into the development of the territory [27] and the strengthening of knowledge, values and local autonomy [63].

Along the same lines, but based on studies located in other countries, stand out as determinants of the processes, economic issues (accessibility, price, cooperation, subsidy) and the need for the development of local and institutional capacities to contribute to the sustainability of the renewable energy projects (including: technical assistance and communication) [7,39]. From the perspective of social analysis, are also added as key to the acceptability of a renewable energy development: the motivation of the rural population by the real difficulty of access to conventional sources of energy, the environmental benefits they generate the community participation and decentralized approach in the use of these technologies [40]. In global scales, several authors emphasize about the systemic aspects of the incorporation of renewable (intervention policies, market structures, knowledge infrastructure, interactions between actors) [9,17] and agree to raise as a critical element, the articulation of public policies predictable and stable [11,15,16,18]. Three key points are made explicit in this regard: the urgent need for an integrated approach to energy planning and consistency in government policy and regulation, the internalization of social and environmental benefits for the posing and sustainability of these incentive measures, and design policies in accordance with the various types of renewable, currently at different stages of research, development and application.

Interestingly, the meeting points between the mentioned researches in the previous paragraphs are multiple. However, aspects related directly to local development and economic aspects did not emerge explicitly as determining factors in the cases analyzed in this study. This is explained in the beginning because the technologies associated with the projects analyzed (solar water heaters) were aimed at resolving a family need and not to promote regional economic development. On the other hand, they are fully subsidized projects by organizations outside the community, so that financial constraints were not perceived by users. However, the research team agrees to specify both as fundamental factors in the development of the processes of socio-technical adaptation. The contribution to local development is related among others, to the use of local resources (materials, organizations and labor) for the design, construction, installation and maintenance of technology, and the possibility of giving added value to local production. Economic aspects refer to complex and diverse issues such as investment and maintenance costs, environmental and social externalities, access to information and resources, etc. factors cited in the literature.

The perspective of planning and the management of public policies were not detected either and boarded in solar projects of heating that were analyzed in this work. On the one hand, this responds to the approach that was centered in precise cases of solar transference technology and not in the integral analysis of the problematic of renewable energies in the zone. However, saving the difference of scales, manifolds factors agree in being identified to the sustainability of the interventions: consideration of the multi-dimensionality of the processes, continuity and pursuit of the actions, environmental perspective and of social inclusion, importance of the information and formation of capacities, and relevance of the interaction between actors.

This last observation leads us to reflect on the *diversity* of experiences, projects and contexts. Each situation of socio-technical adequacy is a 'world' in diversity of views, cultures and needs, potential resources, possibilities for action, available technology, installed capacities, etc. and therefore require the opening up of researchers and technicians to the appropriateness of the methodologies of approach. So far, the focus of research in relation to the 'transfer' of technology (particularly renewable energy) was primarily focused on analyzing the views of technical, economic and, more recently, environmental processes. Some progress began to emerge in the study of the social aspects [7,16,40]. However, it is the intention of this study to emphasize the multidimensionality, complexity and integration of all these aspects (social, environmental, technical, institutional, economic, geographical and cultural) for the development of socio-technical adequacy processes of renewable energy and other technologies. Which of all these aspects is the most important? There may be one more crucial than any other, but will undoubtedly be the interaction between them what defines the 'success' or 'failure' of interventions. The lessons learned will simply enrich the methodological approach of each process, unique and unrepeatable. The potential in social, environmental and economic benefits of renewable energy in rural areas is widely agreed [5–14,27,39,40,53,54,63]. Efforts should then focus on the study of the processes. It is expected that the main contribution of this paper is to provide some concrete elements for reflection and discussion, and encourage a holistic, integrated and participatory view to approach them.

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